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ScienceDirect

Procedia CIRP 45 (2016) 163 – 166

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3rd CIRP Conference on Surface Integrity (CIRP CSI)

Effects of Broaching Operations on the Integrity of Machined Surface

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Abstract

Surface integrity describes the characteristics of a workpiece surface after being modified by manufacturing processes. It is an important term particularly where safe performance of parts is a prime concern. Broaching, is a unique machining operation where one stroke of the tool delivers the finished product; hence, the broaching regime directly governs the quality of final part during service life. This paper investigates the effects of broaching on the subsurface microhardness, and subsurface plastic deformation for AISI12L14, AISI1045, and Al7075. The results show the effect of broaching operation on the integrity of the machined surface.

Peer-review under responsibility of the scientific committee of the 3rd CIRP Conference on Surface Integrity (CIRP CSI)

Keywords: Surface Integrity, Machining, Broaching Operation

1. Introduction

All of the parts and components to be used in industry must accomplish a specific task regardless of severe working conditions that may exist during their service life. Thermal shocks, dynamic loading and unloading (fatigue), and working in corrosive environments are few examples of such tough conditions which impose several limitations on the design of parts and eventually manufacturing processes to be implemented. Therefore, each part either working solely or working together in an assembly must be well designed and precisely manufactured to work in a reliable and safe manner [1].

The quality and condition of the surface is one of the key factors that plays an important role in durability and sustainability of parts during their service life. The surface of a workpiece can be highly affected by machining processes in which a surface layer is removed by a hard cutting tool in several passes. It has been demonstrated by several researchers [2-5] that fatigue failure almost always occurs on or near the workpiece surface where the impact of the machining process is dominant. Fracture and failure is mainly caused by surface defects. For this reason, machining operations are usually followed by some finishing operations such as grinding, sand blasting, shot pinning, etc. to either improve the quality of surface, or to decrease the density of small cracks and to impose compressive stress in order to prevent crack propagation. These typical finishing operations remove defects from surface or induce compressive residual stresses to decrease the effects of previously applied machining process and to improve the reliability of workpiece. However, it must be noted that finishing operations, especially grinding, are usually costly and time consuming; hence, their application must be minimized if not completely eliminated.

Among the machining operations, broaching is an old but important process which has a great capability in producing profiles that cannot be achieved by other machining processes. These profiles include but are not limited to keyways, guideways, and splines. In broaching, all of the roughing, semi finishing, and finishing steps are accomplished in just one stroke of the machine, thus performing additional operations for surface modification is not common. In the absence of finishing operations, the quality and the integrity of the broached surface is directly determined by the process itself and cannot be modified later.

The main objective of this paper is to investigate the possible effects of the broaching process on integrity parameters of the

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doi:10.1016/j.procir.2016.02.352

workpiece surface such subsurface microhardness and subsurface microstructure.

2. Surface Integrity in Broaching

The term surface integrity can be used to describe the features and characteristics of surface region of a component. A combination of several factors such as stress and elevated temperatures generated during machining can cause defects, or alterations of the surface characteristics such as microstructure, microhardness, plastic deformation and residual stresses in the machined part. These defects are produced from different machining processes and they can significantly affect the performance of the final component. Therefore, investigating the effects of process parameters and machining strategies on the machined surface before utilizing a certain machining process is an important subject. Surface integrity is generally divided into two main categories which are topography characteristics and surface layer characteristics. Surface roughness, waviness, form errors, and flaws can be classified under the topography characteristics while the surface layer characteristics include, but are not limited to, residual stresses, sub-surface microhardness, plastic deformation, recrystallization, and phase transformations. Surface topography and surface layer characteristics are important as they have a major contribution to strength and performance reliability of parts in many cases [5].

In broaching, the number of cutting edges which are simultaneously engaged with the workpiece is normally higher than other machining processes; thus the overall magnitude of cutting forces is higher. Each cutting edge removes a layer of material from the workpiece surface and it introduces plastic deformation to the machined surface. In this case, if the rise per tooth (the difference between the heights of two successive cutting teeth) is less than the depth of cold-worked layer, the next cutting edge then encounters the previously cold-worked layer and it must remove a harder layer of workpiece surface in comparison to the previous cutting edge. As a result, the magnitude of cutting forces as well as plastic deformation of workpiece surface and depth of cold-worked layer are increased after each tooth passes.

Although several prestigious research papers can be found dealing with surface integrity generated by machining processes [6-11], broaching has received little consideration in research and literature [2]. One of the few research works investigating the surface integrity of broached surface has been presented by He [2] in which the effects of broaching process on the surface roughness, subsurface microhardness, and subsurface residual stress of a titanium workpiece was experimentally examined. However, the effect of each individual tooth was not considered in He's research. Comprehensive study of surface integrity introduced by broaching is required to avoid any problem that can cause the part or assembly stop working.

3. Test Configuration and Experimental Setup

To conduct broaching experiments as close as possible to an industrial application, a wheel coupling which is a common part in the automotive industry was selected as the sample workpiece. Fig 1 illustrates a schematic view of the above mentioned coupling.

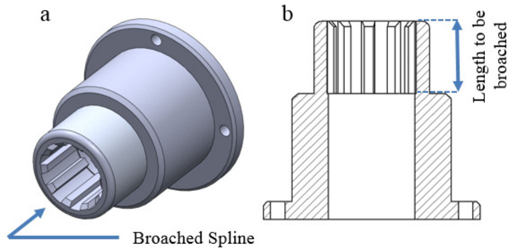

Fig. 1. Geometry of the coupling to be broached; (a) Isometric View; (b) Section View

3.1. Broaching tool

A high-speed steel (HSS) spline broaching tool was used for the experiments. This type of broaching tool is very common in the machining industry, especially for producing automotive parts such as couplings for power trains or sun gears. Fig 2 illustrates the geometric aspects of the implemented tool.

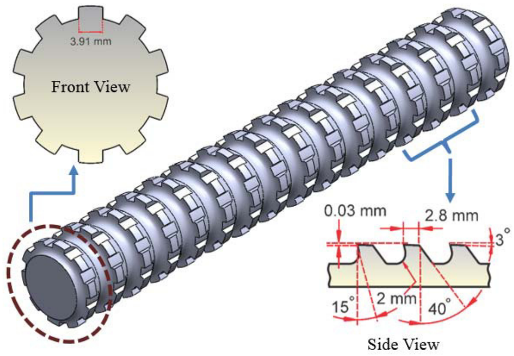

Fig. 2. Geometry of the selected broaching tool

The tool has 44 teeth and the pitch length (distance between two successive teeth) is 10 *mm*.

3.2. Workpiece material

Two types of steel (AISI12L14, AISI1045) and one type of aluminum (Al7075) were selected and used as workpiece materials. The mechanical properties of these three materials were determined by performing standard tensile tests Mechanical properties of the workpiece materials are presented in Table 1.

Table 1. Mechanical properties of the workpiece materials

	AISI 12L14	AISI 1045	Aluminum 7075
$E\ (Mpa)$	200	210	64
$\sigma_{yield}\ (Mpa)$	397	346	135
$\sigma_{ultimate}\ (Mpa)$	663	605	280